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## Paper Session II-B - Management of Long-Term Technology Efforts in a Changing Environment

Barbara N. Pearson

*Simulator Operations and Technology Division, Mission Operations Directorate, NASA Johnson Space Center*

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# Management of Long-term Technology Efforts in a Changing Environment

Barbara N. Pearson  
*Simulator Operations and Technology Division*  
*Mission Operations Directorate*  
*Nasa Johnson Space Center*  
*Houston, Texas 77058*

## Introduction

The Space Station Training Facility (SSTF) is a high-fidelity, ground-based replication of the orbiting International Space Station (ISS) that has been under development for over five years. Within the next two years, we will become operational with the facility, however, we will also continue development that mirrors the continuing assembly of ISS through the year 2002. Since our development began, significant programmatic change has occurred: Space Station design, need dates for SSTF training, available funding, and the funding profile. The industry is experiencing a high rate of technology change and the eleven years we will have spent in development represents a significant amount of time for technology advance. The point at which a new technology becomes viable is not always clear and, likewise, building an architecture that is flexible enough to accept whatever the future may require is not easy. To accommodate programmatic and technology changes, we are changing management paradigms and with schedule and cost more significant than ever before, we and our contractor, Hughes Training Incorporated (HTI), must be able to turn on a dime. We plan for change because, today, change is normal and it is felt that, through flexibility, we have significantly improved our ability to manage long-term technology development in a very fluid environment.

## The Changing Environment

### Schedule

Our entire development schedule is based on the ISS Program's schedule. From the assembly sequence to the availability of vehicle data, we must remain in synch with the program. Although the SSTF is a replica of the space station, our SSTF must be operational for training astronaut and mission controller training before the vehicle is ready. Over the years we have spent a significant effort adjusting to schedule change, and this focus on replanning resulted in low productivity.

The key to dealing with schedule change has been to develop the content that is least likely to change earliest in the development plan. The basic simulator architecture can be accomplished first, while allowing the vehicle specific modeling to be developed last. By leaving the vehicle details until as late as possible, we are assured better design data from the Program. Developing the architecture separately from models also assures clear separation between vehicle modeling and simulator infrastructure. This separation means changes are more easily planned and accomplished.

It is extremely important that we describe the facility in terms of operational capabilities and not just focus on a set of loosely coupled requirements. An operational description allows groups of requirements to move and change as the program changes, and is much easier for the user to relate to than the simulator architecture. An operational description ensures that requirements are not lost in the shuffle, and it not only ties requirements together, but also provides a frame of reference for defining the implementation of the requirements.

### Funding

During the life of the space station program efforts, the funding has been greatly reduced. Additionally, the funding profile, or the amount of funding provided each year, has significantly changed. When we weren't replanning to meet new funding marks, we were defending our current funding profile. The pressures to change resulted in poorly planned modifications to our plans, and as simulator functionality changed to meet funding constraints in the current year, we began to lose sight of the detailed content in the out years. Our response time for meeting new funding challenges was too long, and to deal with the funding changes, we have not only changed our planning process, but we have driven down cost by taking on higher technical risk.

It has taken time, but we are evolving toward more top down planning to ensure that the overall simulator architecture is not compromised. We also spend less time on detailed planning in the out years, and more on high level planning and early prototyping. To maintain operational capabilities, we prioritize requirements, and as the funding shrinks, we have sought less expensive implementations of our requirements. As an example, the level of training that the crews and flight controllers need requires that we run real-world flight software. Using MDM FEUs became too expensive during the last year, so we have taken on the challenge of building MDM emulators. These emulators are built from COTS equipment. This is not a trivial task, and has added risk, but with this and other similar modifications to our planned implementation, we have managed to stay within our shrinking funding profile.

### Concurrency

To reiterate, the simulator must be ready prior to the vehicle, but it must be an accurate representation of the vehicle, therefore, concurrency is paramount to the success of the SSTF. Since we began the development of the SSTF, space station has been redesigned several times. As the station design changed, so has our design, resulting in a certain amount of throw away work. Periods where we know a design change is imminent, and we have no official documentation of what the design change will actually be, is of great concern. It is a balancing act to decide what work to stop and which work must continue. We have learned to begin work as late as possible on vehicle unique efforts, put the simulator infrastructure in place early, and establish good interfaces with the program to assure we stay in synch.

The ISS Program, through the Operations and Utilization IPT, has helped us gain direct access to PG 3 engineers to assist with our data gathering and possible reuse of PG 3 Matrix X models. Within the Mission Operations Directorate, we are working with the Program to establish permanent points of contact at each PG to assist in the concurrency task. Additionally, as we

move toward a completion form contract for delivery of the SSTF, we have asked HTI to cost the option of deleting our involvement in providing vehicle design data to HTI. Whether we continue to provide information through the Program, or require HTI to acquire the data on their own, will be a cost versus risk management decision.

There are other methods to gain the required vehicle information. Our contractor, HTI, has a contract with Honeywell to provide MDM design data and development assistance for our MDM emulators, HTI has a contract with Rocketdyne for the reuse of their primary electrical power system simulation, EPSIM, and to provide assistance with electrical power system flight software. We also have an agreement with the Automation, Robotics, and Simulation Division (ARSD) for them to provide us with their engineering simulations of the SSRMS for reuse.

Simulation of the International Partner elements has brought additional challenge. The level of information on these elements has not been sufficient to build a simulation. The agreement we have reached for the development of the Russian Segment Trainer uses a unique approach. We are providing our common platform hardware, Silicon Graphics, and our software infrastructure and environment models to RSC - Energia. RSC - Energia will develop the systems models to run on the platform. This approach provides common hardware and software here and in Russia, and is currently underway.

### Technology Changes

With the speed at which technology now changes, grand, long-range plans get modified numerous times. The multi-year procurements that these grand plans require are not possible, and centralized architectures are not supported. The SSTF is being built with an open architecture that avoids vendor unique solutions, and we use a distributed architecture with industry standard interfaces that will provide for ease of obsolescence replacement and upgrade.

However, the advancements in software have provide their own unique problems. The ISS Program moved to the use of graphical model development tools, i.e. Matrix X, which eliminated a great deal of the paper design data that we would normally have available. We have looked at, as a minimum, using Matrix X as a data source, and as a maximum, reusing models in the simulator. We have struggled with the reuse of these models. First, the models that we have seen are very detailed engineering models, i.e. a fan model will take into account the humidity of the air it is flowing. This level of detail is far below what is required for mission controller and crew training, and because the models are very detailed, we have also found that the models are not pure Matrix X modeling. In some instances we have found embedded assembly code. The reuse of these models is further complicated by the lack of documentation and test case information. When acquiring separate models and trying to integrate them, information on the use of variables and the rationale behind their values is required, and without test data, it is difficult to know where a problem exists if the model does not run as expected. Direct reuse of the Matrix X models is further complicated in that state variables cannot be captured for normal simulation modeling and control. By looking at one or two models in detail, we have been able to determine the best path, overall with a minimum expenditure. Although we are still planning on reusing the models where ever we can, we feel the best use of these Matrix X models is for data harvesting.

## Changing Management Paradigms During a Project

All of the changes that we have discussed thus far usually translate into higher costs. As a team, the civil service and our contractor management are making changes to mitigate cost growth and to further lower the cost of development and operation. During the last two years significant change has been underway: the development contract was bought out by Hughes Inc., PMS requirement was levied on HTI, IPTs established with users, and HTI given responsibility for demonstration of SSTF operability in addition to development responsibility. All of these changes are resulting in an improved team approach between the Government and the Contractor. The Government is moving toward a more rigorous management approach, and HTI is stepping up to accountability and responsibility for delivering the desired product.

### Changing the Contract Form

One of the changes that NASA has undertaken in the last year is to move contracts from level-of-effort (LOE) to completion form (CF), and for contractor and government personnel who have worked their entire careers in an LOE environment, this has been very difficult. Many of the people involved professed eagerness to make the change, but actual effort indicates business as usual. We and our Contractor have put forth considerable effort to ensure that our contract is not a support contract cloaked in completion form buzz words. First, HTI must take accountability for producing a product that meets our needs as described by the contract, and secondly, we must take responsibility for the management of that contract.

We feel that the rigor and discipline that CF requires is greatly improving our ability to provide a fully operational product to the program, and the emphasis on an end product has helped encourage HTI to make management changes and to improve their planning and costing capability, and we have tailored the contract to ensure that HTI has the latitude to become more cost effective. And we further encourage cost effectiveness with an incentive clause that allows HTI to share in its success in reducing costs. The fee structure that we are putting in place emphasizes our focus on an operationally sound product where each flight configuration with its associated training load is a product and is evaluated separately. The quality of each of these products and the cost of providing these products are tied together to ensure that the quality is not adversely affected by cost cutting measures.

### Establishing a PMS

Another change that is producing much needed management rigor is the establishment of a Performance Measurement System. Although the switch from LOE to CF required quite a shift in mind set, the shift to using earned value to manage a project continues to be a major adjustment process. There are two key points: the establishment of the earned value (EV) system and the use of the system.

First, the establishment of an EV system has been a tedious process. The initial earned value system attempted by our contractor was a home-grown set of software that our contractor

struggled with for several years. After HTI bought out the development contract, they realized that the Government's requirement for EV reporting was here to stay, and they have brought in corporate resources to help put in place a commercial-off-the-shelf system. However, having the tools in place is much like having Excel software. You now have a mechanism for building a spreadsheet, but you must have meaningful information to load into it. After years of LOE, having to plan and cost the plan, and then having to abide by the results is a major culture shock. Our current efforts include the baselining of the SSTF plan through 2002. To do this, we are ensuring that the measurement system is tied to the real work that is being accomplished by defining milestone completion criteria. Once the system is certified and the baseline is loaded, we will perform a Technical Baseline Review to ensure the baseline is indicative of a plan that will result in the expected SSTF. By the beginning of FY 97, we expect be fully operational with the CF contract and a certified PMS.

Secondly, the movement toward the use of PMS is still underway. The greatest challenge to using the system has been for people to adopt to using the system and not continue trying to manage everything twice. Many people have held on to their own way of determining progress while also filling in the data that will be reported in the PMS monthly reports. This is a cost that we must eliminate. It is now clear that the culture and the tools to move to a certified PMS were both a problem. When we attempted a home grown system the culture prevented the development of adequate PMS tools and now, after putting a tool set in place, we have been much more aware of, and are now able to concentrate on, the serious culture problem.

We all understand that our programmatic interface must be more orderly than in the past. We have a plan and we are holding the contractor fully accountable for the product. Cost growth can be stopped if we understand where the ISS Program is headed and can plan accordingly.

#### Establishment of IPTs

Another recent management shift has been toward the use of Integrated Product Teams (IPTs). Our effort has been unique in that we have shifted to IPTs well after starting the project. For many years our method of communication with our contractor was through requirements, and even though we had been operating under an LOE contract, our communication was not very good. It is impossible to "throw requirements over the fence" and expect much in return. Additionally, we had requirements coming from many different organizations with good opportunity for disconnects and overlaps. We established IPTs with the SSTF users to integrate requirements and to provide a level of detail not normally provided in requirements. We feel this is removing the "you brought me the wrong rock" syndrome.

The initial set of IPTs was for the development of vehicle systems models, and we have since moved on and developed IPTs for Operations and Integration. Each IPT includes representatives from the instructor community and our division, with HTI providing a lead for each IPT. Throughout this process, the contractor remains responsible for the product. We feel this process has allowed us to put the requirements in an operational context that helps HTI understand how the SSTF will be used, and affords HTI a higher potential in delivering a product that fulfills the

users needs. With our emphasis on product, this IPT arrangement benefits the Government and the Contractor.

Establishment of the IPTs has not been easy and it is not complete. The IPTs are accountable for their product, and this is a very heavy responsibility for some people. Many individuals have hung onto the old way of doing business; i.e. I write requirements, you build something, then I'll tell you if I like it. Some teams have been very successful, however, some are slow to change. Middle managers continue to want to be fully in control, but training and some movement of personnel is helping. Additionally, HTI is bringing in corporate resources to further help in the development of the already established IPTs, and to develop and put in place an overall IPT structure. We feel this is a significant step toward further streamlining management, and this will also help the transition to CF and the use of EV.

#### Making One Contractor Accountable for the SSTF

Since project inception, the SSTF was to be developed by one contractor and operated by another, and for many years, we have developed and operated other training facilities in this manner. This has lead to less than desirable results.

The development contractor was focused on building to meet requirements with a delivery date in mind. The operations contractor was waiting for the new product. We did not dictate the development contractors development strategy which had evolved into the "big bang", i.e. develop until we can check off the requirements, and then deliver. The operational shelf life of the delivered product was nil. Likewise, we did not dictate operations concepts to the operations contractor. It is sometimes very difficult to introduce state of the practice hardware and software into an older operational simulator, and operations concepts and plans can not be used as is, so conflict usually ensued. The result was much like the difficulty in integrating hardware and software. When the system does not work, is it a problem with the hardware or software? Similarly, when the simulator does not work, is it operations or the simulator?

The SSTF will be designed, developed, and operated by one contractor. Whatever HTI designs and develops, they must also operate, which has led to HTI having an increased awareness of operational issues. Additionally, this allows the use of facilities and tools by HTI as they are developed. The shelf life of these products is thus greatly increased prior to delivery to the customer. Since developers do not work around problems with the infrastructure, problems are addressed much earlier in the development cycle. The design is also influenced by operational expectations where such things as the number of operators, the type of tools an operator needs, and even the notion of having an operator are revisited as the approach to operations is addressed.

#### Conclusion

The SSTF is a highly complex project that has been under development for many years, yet it will not be completed until after the turn of the century. The project has faced a multitude of management and technical challenges, and although the outcome has not always been ideal,

efforts have been made to focus on, and learn from the mistakes of the past. The notion of management processes requiring a stable environment may have applied at some point, but not today. As the needs of our customer, the ISS Program, changes we must immediately react regardless of other factors, and we must meet funding, schedule, and content needs. We feel that the lessons that we have learned through the management of challenges over the past two years are applicable to any long-term technology effort.